Modeling of Spatiotemporal Dynamics of Biogeochemical Cycles in a Changing Global Environment

Fatih Evrendilek*

Department of Environmental Engineering, Abant Izzet Baysal University, Golkoy Campus, 14280 Bolu, Turkey

Biogeochemical cycles refer to the coupling of hydrologic cycle, gaseous cycles, and sedimentary cycles and are the ultimate drivers and regulators of ecosystem goods and services upon which (non) human life depends [1,2]. Continuous exchange of energy, matter, and information among the atmosphere, hydrosphere, biosphere, pedosphere, and lithosphere fueled by the sun renders spatial (geographical) and temporal (past, present, and future) interdependence of ecosystems inescapable [3,4]. A recent example that has reminded mankind of this interdependence and interconnectedness is global climate change, an illustration of how locally isolated human activities of burning fossil fuels and altering land use/cover cumulatively have transboundary impacts on global climate which in turn feed adverse effects back to ecosystem health, human well-being, and economic welfare on the local scale. However, global environmental change is a broader concept than global climate change that goes beyond the alteration of terrestrial, aquatic and atmospheric biogeochemistry. In addition, global environmental change encompasses the unprecedented rates and daunting scales of impoverishment of terrestrial and aquatic biotic and abiotic resources such as losses of biodiversity and natural habitats, landscape fragmentation, encroachment of invasive species, air, and soil and water pollution as well as impoverishment of social, economic and political structures such as poverty, hunger, distributive injustice of income and power, unemployment, and alienation from nature [5].

Biogeochemical cycles operate at temporal scales of seconds, months, years, decades or centuries, and at spatial scales of square meters, watersheds, biomes, or the globe. A better understanding of complex interactions, multiple feedback loops and non-linear behaviors inherent in human-nature relationships calls for long-term and continuous monitoring and measurements of time- and space-varying environmental processes. In this context, many monitoring networks, cyberinfrastructure platforms, and long-term experimental stations have emerged for observations of rate, amount, extent, direction, frequency, and severity of environmental changes and for the outreach of dynamic datasets and databases created to decision makers and public [6]. Some milestones in the creation of such data streams include Rothamsted Experimental Station established in 1843, the International Biological Program (1970-1975), Hubbard Brook Ecosystem Study began in 1964, Long Term Ecological Research Network (LTER) started in 1980, the global network of flux towers (FluxNet), optical sampling networks (SpecNet), International Spaceborne Imaging Spectrometry (ISIS), and Automated Land Change Evaluation, Reporting, and Tracking System (ALERTS). The spatial extent of these observatory and experimental networks stretches from the Arctic to the Antarctic and from natural to managed ecosystems including forests, grasslands, savannas, shrublands, tundras, deserts, steppes, wetlands, aquatic ecosystems, croplands, and urban ecosystems.

Today’s process-based and data-driven biogeochemical models have been conceptualized, parameterized, calibrated and validated using datasets of such monitoring and experimental networks. The related literature contains numerous process-based (mechanistic) biogeochemical models such as BIOME-BGC (BioGeochemistry Cycles) [7], CENTURY [8], TEM (Terrestrial Ecosystem Model) [9], and DNDC (Denitrification-Decomposition) [10] as well as data-driven (empirical) models such as multiple regression models, artificial neural networks, and geostatistical models. Regardless of their type, all models strive not only for a better understanding and prediction of ecosystem structure and function of varying spatiotemporal resolutions but also for devising the best adaptive management practices under natural and human-induced disturbances, and uncertainties associated with them. Advances in remote sensing and geographical information systems have immensely improved the spatial (less than one meter to larger than a square kilometer), spectral (panchromatic to hyperspectral bands) and temporal (several times per day to several times per year) resolutions of gathering and analyzing information about biogeochemical processes. In parallel to the huge amounts of continuously streaming data, concerns about data quality control and assurance have intensified, thus seeking new algorithms to deal with stochastic and deterministic noise, data compression, and feature/pattern extraction such as Fourier and wavelet transforms.

Despite all the advances of expertise, technological capability, and state-of-the-art sensors, significant issues still persist with the destruction and degradation of unmanaged and managed ecosystems, the rehabilitation of damaged ecosystems, tragedy of the commons, and bridging the gaps between science and public policy, between micro- and macro-scale ecosystem models and among ecology, economy, energy, education, and ethics (5Es) [3,11]. Nationally and internationally collective investments and efforts are, therefore, needed for the reorientation and reconstruction of institutional regimes towards achieving sustainability by which water, food, energy and social securities, and distributive justice are enhanced and ensured [12,13]. Systems thinking and modeling for a complex dynamic world where social, natural, economic and technological factors are intertwined calls for recognizing and meeting the challenge of incorporating into ecosystem models such soft variables that relate to human values, attitudes and behaviors under the global environmental change.

References

*Corresponding author: Fatih Evrendilek, Department of Environmental Engineering, Abant Izzet Baysal University, Golkoy Campus, 14280 Bolu, Turkey. E-mail: fevrendilek@ibu.edu.tr

Received November 12, 2012; Accepted November 13, 2012; Published November 15, 2012


Copyright: © 2012 Evrendilek F. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.


